On Line Silicon Dosimeter for LHC Machine electronics

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Outline

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- Functional Requirements
  - Dynamics
  - Accuracy
  - Radiation tolerance read out board
- Dosimeters and remote readout
  - Dose – RADFETs
  - Displacement Damage - PIN diodes
  - SEU – SRAM counter
- Implementation
- Preliminary radiation tests results
- Times Scale & costs
- Conclusions

Motivation

- Monitor degradation of electronics due to radiation when beam “on”
  - 10.000 electronic crates in ARCs and DS
  - 100 racks – 750 electronic crates in RRs in Points 1,5,7
- Anticipate replacement of electronics degrading by TID or DD
- Confirm any statistical failures caused by radiation (SEE) not by MTBF
- Focus on radiation damage in silicon (semi conductors)
  - **TID :** Total Ionising Dose in Si [Gy]
  - **DD :** Fluence of 1 MeV eq. neutrons [cm^{-2}]
  - **SEE :** Fluence of hadrons E > 20 MeV [cm^{-2}]
- Confirm FLUKA/MARS/GEANT4 predictions of radiation levels
- Confirm shielding efficiency – confirm staged implementation
- Complementary to BLM data to understand LHC operation

Requirements

- **Accurate monitoring of a mixed radiation field during operation :**
  - Inaccuracy : **TID :** 10 % **DD :** 20 % **SEE :** 10 %
  - Dynamics : **TID :** 0.1 Gy/s **DD :** 1E6 cm^{-2} s^{-1} **SEE :** 1E8 cm^{-2} s^{-1}
  - Tolerance monitor board : **TID :** 200 Gy **DD :** 1E12 cm^{-2} **SEE :** none
- **Flexible and scalable :**
  - Number of monitors should vary according to needs
  - Monitors have to be placed next to any tunnel electronics (on the cable trays and under cryostats main magnets)
  - Radiation Monitoring of UAs, UJs, bottom of the pits, US45, RRs …
- **On line data via "standard" CERN controls infrastructure**
  - WorldFIP fieldbus network at 33 kbps in tunnel
  - Gateways with Ethernet in surface buildings (SRs)

Total Dose Dosimeter

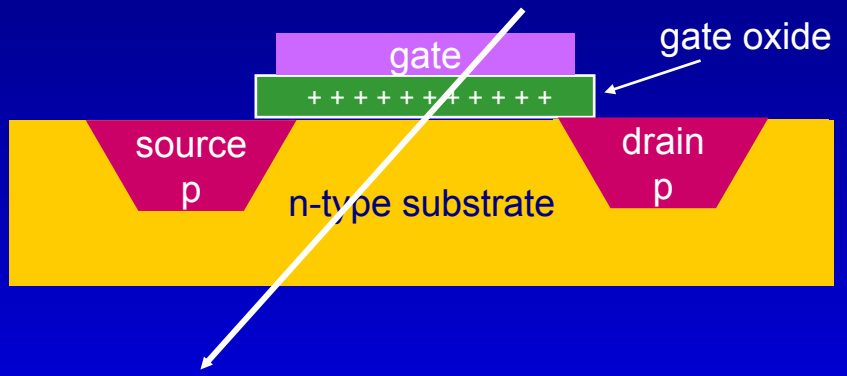
Basic principle

MOS transistor

- Amplify signals
- Logic
- …

Characteristics under radiation

- Conductivity decreased
  - Creation of electron-holes
  - Positive charge trapped
- Conductivity change is *proportional* to the Total Ionising Dose
  - Information stored in gate oxide
  - Read information via Electrical measurement



Thomson & Nielsen RADFET

Advantages

- Widely used
- Precise calibration curve for ^{60}Co:
  10 Gy give $\Delta V = 0.9$ V
- Various gate oxide thicknesses
  - TN100P (oxide 0.10 um)
  - TN250P (oxide 0.25 um)
  - TN502P (oxide 0.50 um)

To be determined

- Optimised readout protocol
- Selection of correct gate oxide thickness
- Annealing behaviour

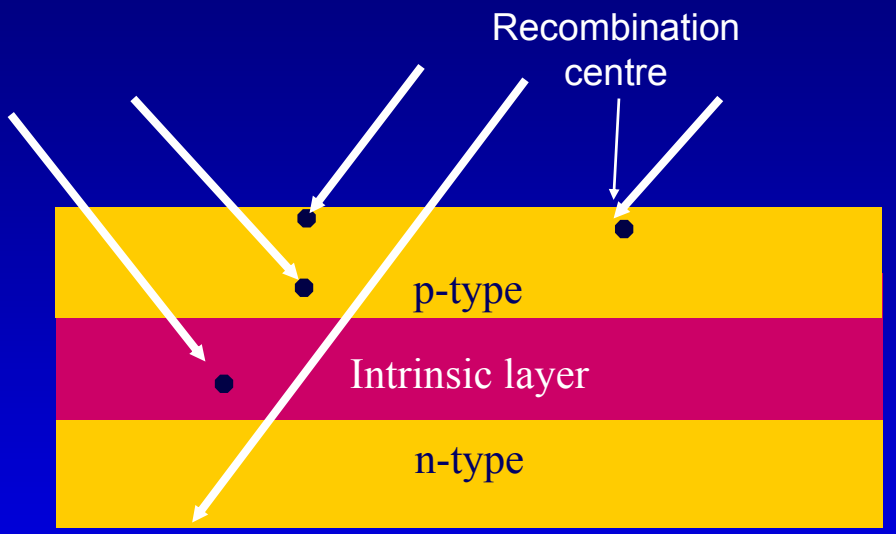
T&N RADFET 0.25 um

Displacement Damage Dosimeter

Basic principle

PIN (p+/n/n+) diode

- variable resistor at RF frequencies
- resistance is determined by a forward current of I = 1-100 mA



Characteristics under radiation

- Conductivity reduced
  - Decreasing minority carrier concentration
  - Decreasing minority carrier life time
- Conductivity change *linear dependent* on 1 MeV equivalent neutron fluence

SIEMENS PIN photo diode

Advantages

- Widely used
- tested in ‘93 by TIS/RP
- Cheap and easy to use
- Linear response

To be determined

- Optimised readout protocol
- Increasing sensitivity at low fluences
- Annealing behaviour

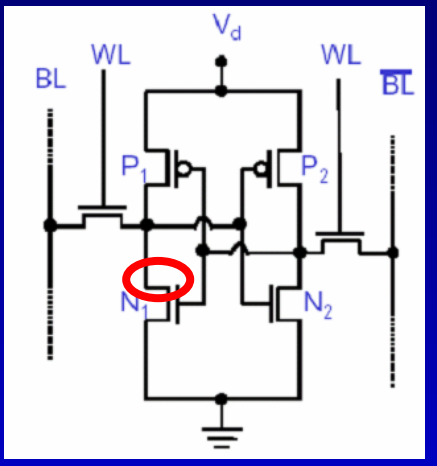
SIEMENS BPW34

Single Event Dosimeter

Basic principle

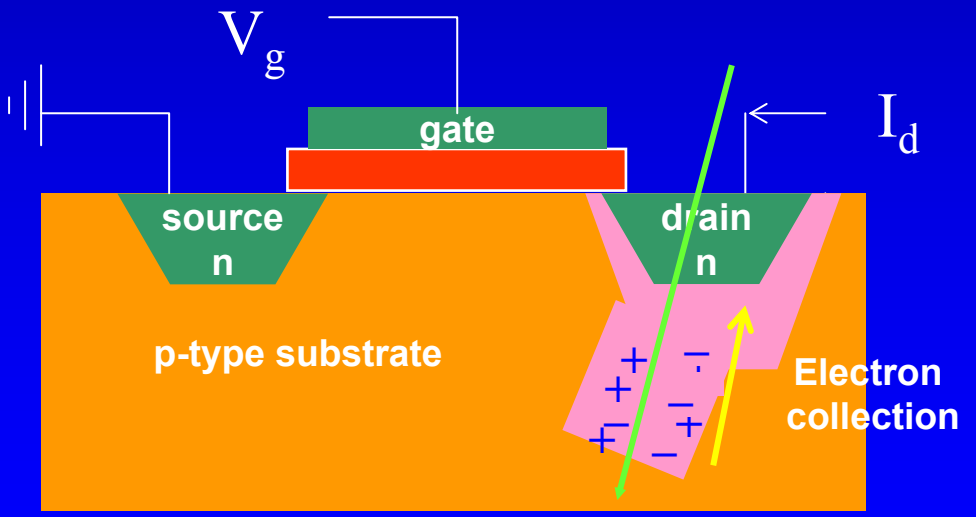
SRAM memory

- CMOS 6 Transistor SRAM cell
- P and N type
- Storage of logic data



Characteristics under radiation

- Logical transitions
  - Creation of electron-holes
  - Fast charge collection – current spike
- Nbr of transitions *proportional* to the hadron fluence E > 1 MeV
  - Information stored in memory
  - Very fast read out possible

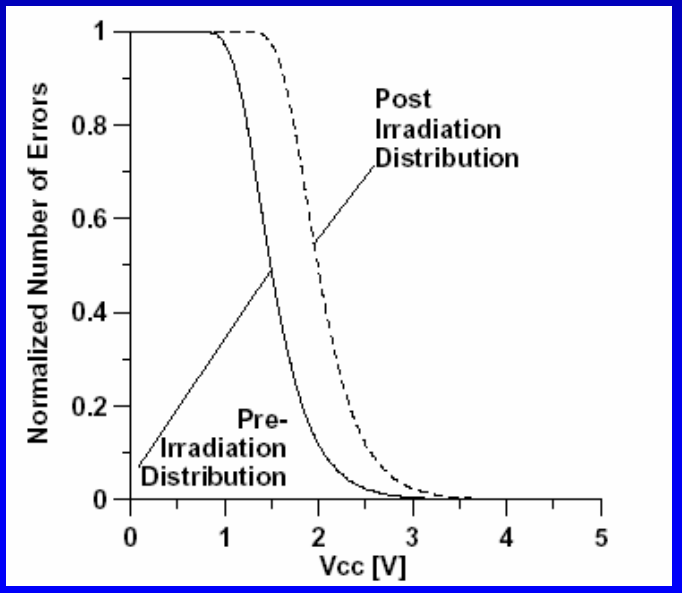


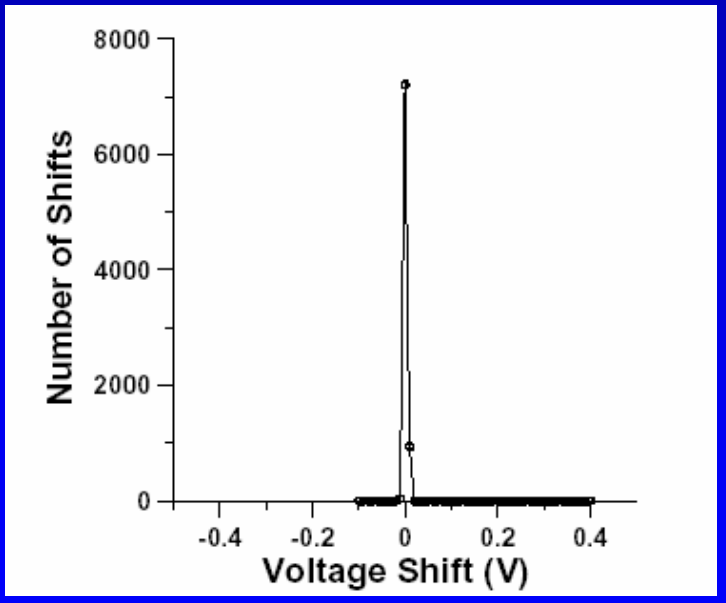
Toshiba SRAM

Advantages

- Commercially available
- No latch up observed
  (5 Volts, 0.4 um)
- Total Dose effects small

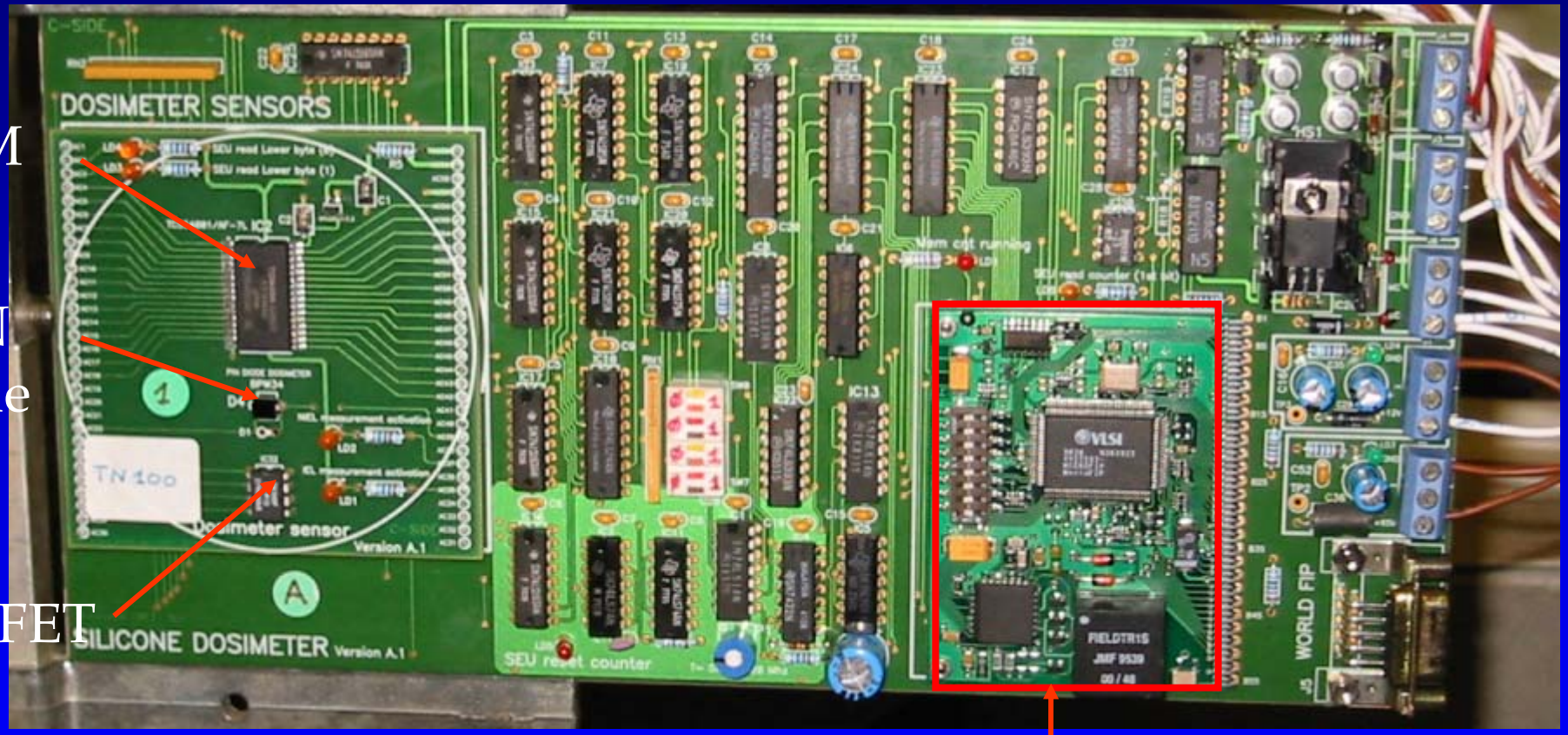
TOSHIBA TC554001AF-70L



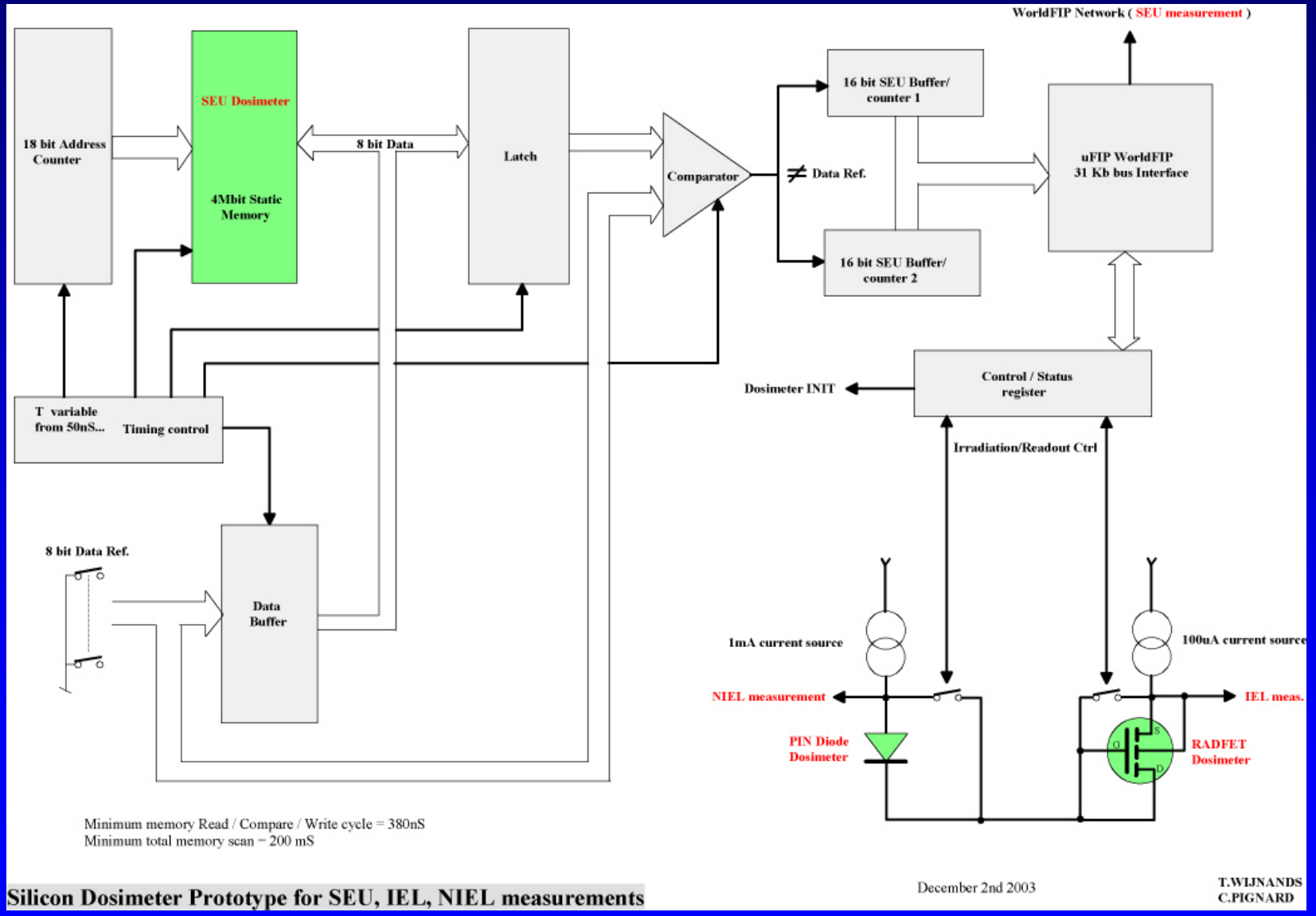


L. Scheick, G. Swift, NSREC Monterrey 2002

Prototype Radiation Monitoring board



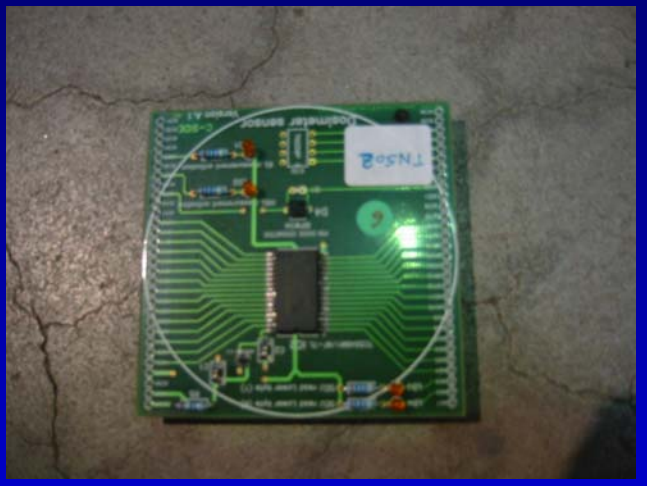
Radiation Monitoring board schematics

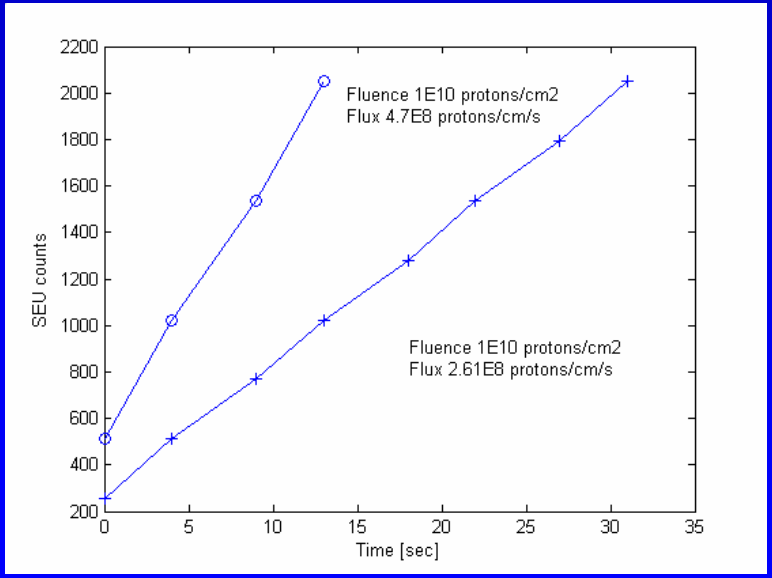


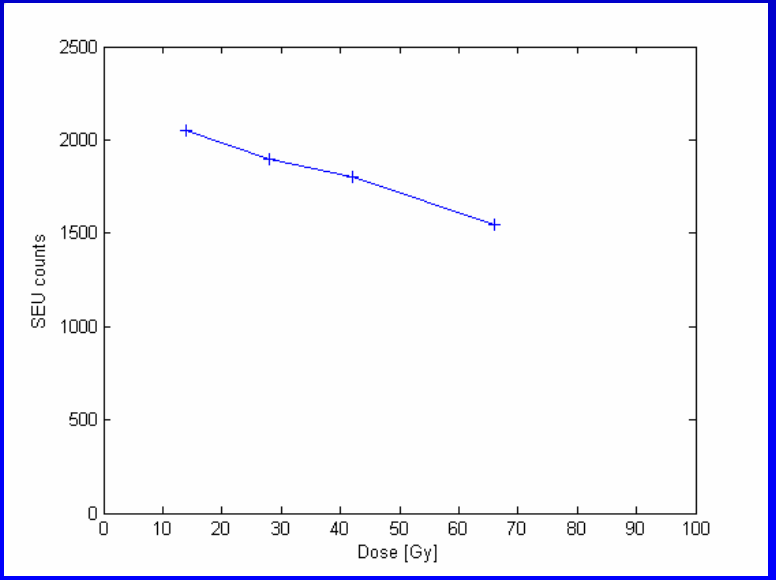
Single Event Test (1)

60 MeV proton beam at PSI

- Irradiation of SRAM only
- Check Dynamics :
  - Flux : 1 – 5 x 10^{8} protons cm^{-2} s^{-1}
  - Fluence constant : 1 x 10^{10} protons cm^{-2}
- Check Total Dose dependence
  - Total dose : 0 -70 Gy
  - Fluence constant : 1 x 10^{10} protons cm^{-2}



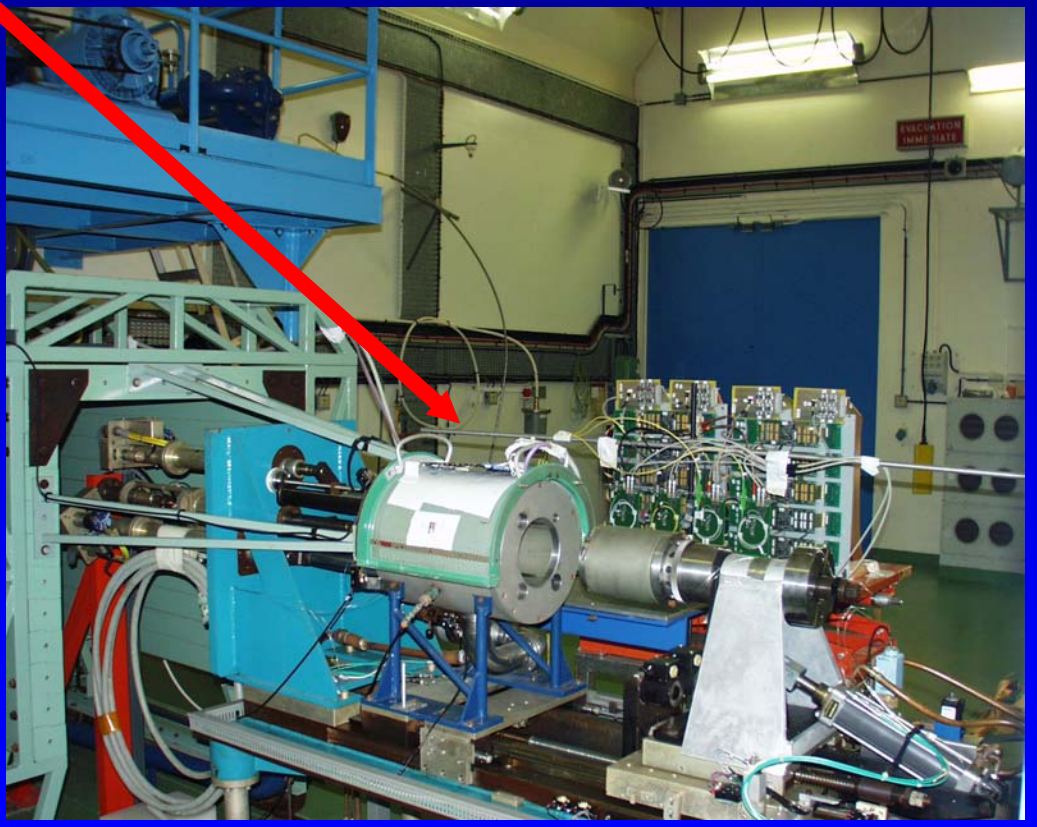




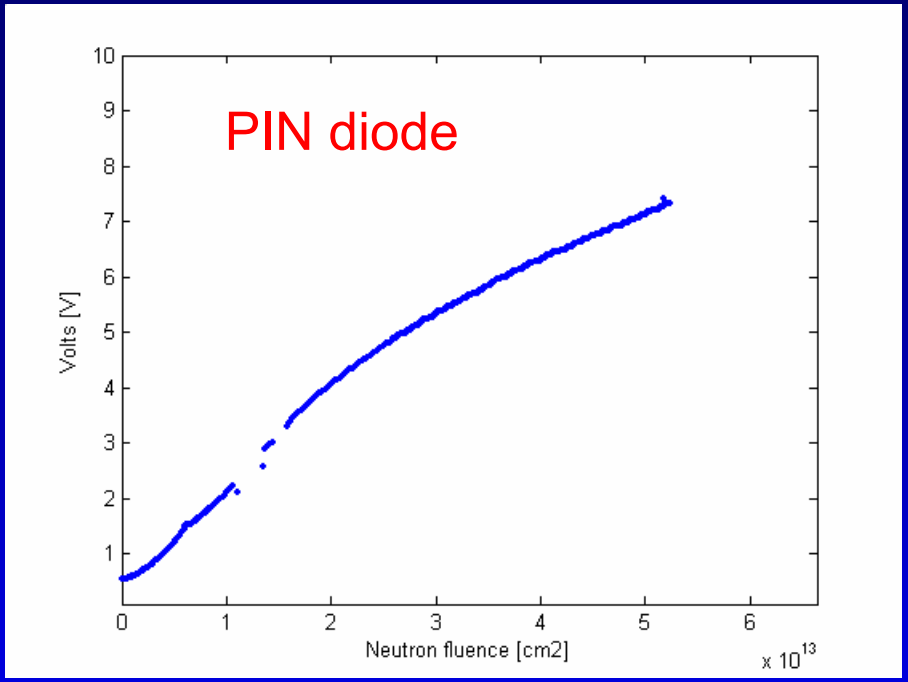
Neutron Radiation Test (1)

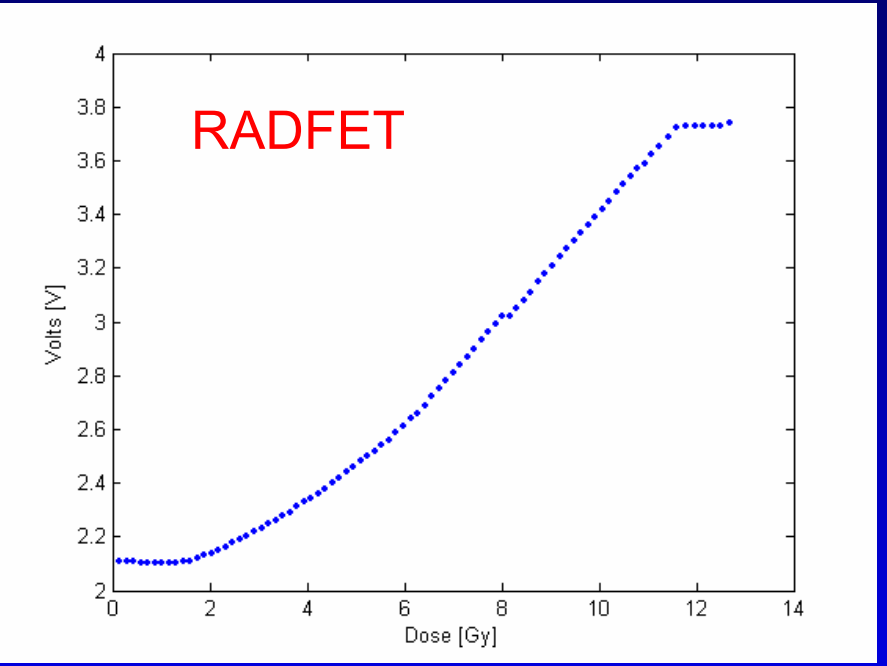
0.8 MeV neutrons at PROSPERO

- Irradiation of entire card
- On reactor core : 0.8 MeV neutrons
- Max 1 % error on dosimetry



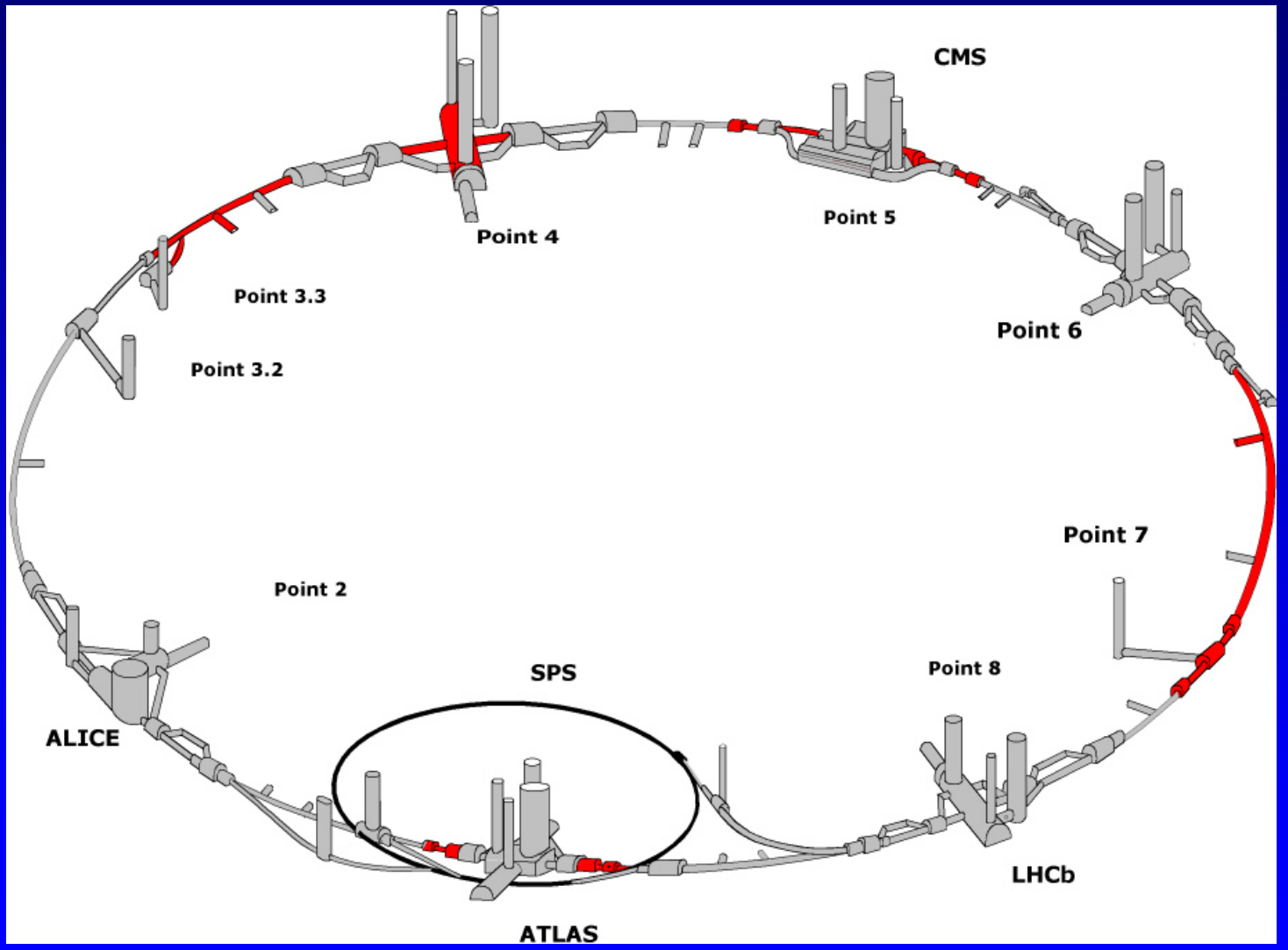
Neutron Radiation Test (2)





- Readout current 1 mA for PIN & 100 μA RADFET
- Radiation parameters (reactor at 3 KW)
  - Flux : 2.9 x 10^{10} neutrons cm^{-2} s^{-1}
  - Fluence : 6 x 10^{12} protons cm^{-2}
- PIN diode : V_F=1 Volt -> 6.6E12 neutrons/cm2
- RADFET (0.1 um) : V_{SG} = 0.1 Volt Gy ->1.2 Gy [Si]
  - **VERY GOOD agreement with manufacturer data : 0.1 Volt ->1 Gy !!!)**

Proposed layout for the LHC



Timescale & Cost estimate

- WorldFIP fieldbus installation
  - 200 connections
  - 20 km cable in tunnel
  - Fibre connection to surface buildings

  130 kCHF
- Dosimeters and remote readout
  - 100 readout boards
  - 100 dosimeter cards

  80 kCHF
- WorldFIP cabling
  - Point 7-8 during local cabling campaign (before 1 March 2004)
  - Other points during signal cabling campaigns
- Operational in sector 7-8 before sector test in 2006

Conclusions

- Silicon dosimeters will be very usefull
  - Diagnostic tool
  - Shielding
  - Operations
- Dosimeters and remote readout have been identified
  - Dose – RADFETs (Thomson and Nielsen)
  - Displacement Damage - PIN diodes (SIEMENS)
  - SEU – SRAM counter (Toshiba SRAM)
- System can be operation before sector test in 2006
- Future work
  - Complete the calibration work (read out protocol)
  - Data on annealing (in collaboration with CMS)
  - Final prototype for use in tunnel to be tested in TCC2 next year
    - **ADC based**
    - **On board power supply**